On Solutions to the Bio-heat Equation

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***Abstract*—** The bio-heat equation is the equation that governs the power equilibrium inside biological tissue by summing the power influxes into a given area and balancing it with losses by various effects. A simplified equation is thus the basis for every calculation of the specific absorbtion rate, and the heating of tissue by external electromagnetic fields. Here, we present an approach to solve the bio-heat equation in a hybrid analytical/ numerical way.

Keywords-component; bio-heat equation, SAR value, thermal effects of electromagnetic fields

I. INTRODUCTION

The subject of our study is represented by the influence of electromagnetic fields on human bodies, focusing on tissue and cell levels. Generally speaking, the main questions we intend to answer are:

- "How the heat distribution would look if, inside a radiated human tissue with an electromagnetic field, there are present some magnetic nanoparticles?",
- "What would be the most effective arrangement of those nanoparticles so that a specific volume of tissue would achieve a desired temperature?",
- "What should be the best frequency and amplitude of the electromagnetic wave that radiates the tissue so that it would reach a particular temperature?" and
- "How long would it take for a volume of tissue to get heated up to a specific temperature?".

Answering these questions would be a good and solid starting point for the field of medical treatments based on electromagnetic stimulation of specific parts of the body previously "filled" with magnetic nanoparticles. It is a known fact that the proteins' chain brakes when a cell reaches 42°C, so having a more accurate idea of how the heat distributes inside the tissue depending on the magnetite disposal would be helpful in order to better control the exact ill part of the tissue that should be destroyed. It also reaches interest to study the effects of magnetic nanoparticles presence even at a deeper level, respectively at cell layer, and to determine the ratio between the cell volume and the magnetite volume for an efficient and expected result in terms of area/ number of cells which get to such a temperature that negatively affect them.

II. APPLICATION TO KNOWN SCENARIOS

Our work has involved exemplary cases for heat equation, namely a comparison between the analytical and numerical solution for different scenarios, having the goal to prove that the results are the same.

A scenario that might simulate the post-effects of a tissue block, filled with magnetite, radiated by an electromagnetic field can be modeled in the software Comsol based on heat transfer module. The magnetic nanoparticles can be considered heat point sources with a temperature of 42°C, and the tissue can be designed as a 3D irregular geometric body with a normal initial temperature of 37°C. The boundary conditions would also be set to 37°C as no condition form the exterior environment should be considered in this point.

A more complex study case involves both bioheat transfer and electromagnetic waves modules from Comsol, without considering the magnetic nanoparticles heat sources from the beginning. The electromagnetic radiation generates the heat source and, depending on the geometry, dielectric and magnetic properties assigned for each domain (tissue, magnetite), the heat distribution is obtained. Moving forward to the cell layer, the geometry should be more detailed, adding more domains (nucleus, cytoplasm, membrane, magnetite).

III. CONCLUSION

Concluding, the influence of an electromagnetic field on a biological organism is a full potential subject which has to be accurately studied in order to get the answers for the proposed questions that we have mentioned in the introduction. This would lead to a bigger image of what might be done in the medical treatments' field that have the goal of destroying the ill cells and protect the healthy ones.